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SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Need of Standard Specifications for Gray-Iron Castings.

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It is generally admitted that a good practical and commercial set of specifications for use by the many cast-iron purchasers does not exist. A few good sets are in the hands of large buyers, but even these are very different, contradictory, and not intended to cover a wide range of product. Most of these sets have been written to cover one industry only.

It is strange that purchasers of cast-iron have not looked into this question long ago and demanded good, uniform cast-iron.

Probably cast-iron has been discarded from many uses because of its failure in some few instances, even though the failure was due to ignorance of the quality of the iron, or perhaps to abnormally bad iron. It is not too extreme to say that some consider all gray-iron from a given foundry alike and uniform, especially if they know it is made from certain well-known brands of iron. It is likely that with standard specifications and the increase of knowledge necessary to meet these conditions, the use of gray-iron castings will enter into fresh fields because of the certainty of quality. This was the case when steel replaced wrought-iron, for the reason that it was made of a uniformly good quality and was thoroughly reliable.

The foundryman, therefore, should welcome any good commercial steps taken in the direction of securing standard specifications for cast-iron.

Uniformity of product in soft steel is comparatively easy to bring about, and yet the most rigid specifications are in common use by the purchasers of this material.

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Uniformity of product in cast-iron is not easy to attain because of the greater quantity of impurities in it, yet specifications for soft steel are common while for cast-iron they are rare.

In steel, only carbon, phosphorus and sulphur are of prime importance, manganese, silicon and copper being secondary, and all of these impurities exist in very small percentages.

In cast-iron, however, silicon, sulphur, carbon and phosphorus are of vital importance and are present in comparatively large percentages. Furthermore, each impurity is capable of notably altering the quality of the metal. Manganese also as a secondary element is to be intelligently regulated to advantage.

Yet cast-iron with the greatest possible variation in composition is neither watched, inspected nor tested in spite of the immense differences possible, while soft steel which may vary but little in comparison is submitted to a careful examination before it is accepted. This circumstance is not due to the fact that cast-iron is not used at critical points either, because it is used in making columns, the breaking of which may wreck a building, as cast-iron enters into the manufacture of high-pressure valves and fittings that may wreck a boiler or an hydraulic system, as well as into many other important uses.

Not only is cast-iron subject to chemical and physical differences under normal conditions, but, like most cast metals, it is liable to have bad internal flaws and latent defects not possible to detect by any other means than a test to destruction. In many cases these defects are the indirect results of bad chemical conditions, for example, a high sulphur percentage, and it is for this reason, if for no other, that a limit to the sulphur-content should have a place in cast-iron specifications.

PROCESS OF MANUFACTURE.

In certain grades of gray-iron an unusual strength is demanded, and in many instances it is convenient to make this grade in a reverberatory or air-furnace. Under the specifications submitted, either method is permitted, each being believed to be good, but, unless otherwise specified, the cupola-furnace will be used. It is known that some founders produce all grades of castings in the cupola-furnace successfully, by the intelligent use of both iron and fuel.

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CHEMICAL PROPERTIES.

It is believed that light iron-castings should be more free from sulphur than heavy ones, because the presence of sulphur induces chill, shrinkage and such flaws as are grouped under the broad head of "dirty iron." All of these defects are more serious in light work than in heavy; the chill, because it is possible in thin iron and not in thick iron, the latter containing so much heat as to cause it to anneal itself in cooling; shrinkage, because light castings chill quickly, form a small, close grain and shrink more in consequence, whereas heavy castings cool slowly, form large, open grain and shrink much less; and flaws, because a flaw of a given size forms a much more serious defect in a light casting than in a heavy one. It is a fact that flaws induced by the presence of sulphur do not decrease in proportion to the decrease in the bulk of a casting, and it is common to find shot-holes in small castings of about the same size as those in much larger castings.

The sulphur-limits placed in these specifications are within the commercial reach of any well-regulated foundry, and necessitate no extra cost. The low sulphur-limit for heavy castings has been objected to as unnecessarily low, but it is on the safe side and is an insurance against bad flaws and should be retained, for the reason that it does not increase the cost of the iron.

Cast-iron with high sulphur-content is sometimes stronger than with low, because the grain in the former instance is closer, a condition which always tends to increase the strength; but of what use is the extra strength if at some vital point in the casting flaws exist as a result of high sulphur-content, that weaken it and far more than offset the extra strength of the sound parts of the casting.

Even if it is assumed that a test-bar representing a cylinder does show unusual strength and is of high sulphur-content and sound at the point of rupture, the casting itself may contain enough shot- and blow-holes to cause failure.

A high sulphur-content is a menace in any casting, whether it can be detected physically or not, and this impurity should be excluded as far as possible commercially.

PHYSICAL PROPERTIES.

The figures given in Table I. have been taken from as many tests as was possible to accumulate in the short time available after determining the dimensions of the test-specimen. All kinds of iron are not represented, but those that are given show very encouraging results.

I was not able to get reliable information in all cases. The bars are from six foundries, making products very varied in character.

From the same foundries the results of testing the inch-square bars selected at random from recent tests are given in Table II. for comparison, being tests made under exactly similar conditions. Nos. 12,761 and 12,762 were from the same ladle of metal as Nos. 12,759 and 12,760.

The theoretical ratio of strength of the inch-square bar in common use as compared with the arbitration bar is about 0.8 to 1, or, to be exact, 0.867; that is, the inch-square bar is about 80 per cent as strong as the $1\frac{1}{4}$ -in. round bar, all things being equal. The results of the few tests made in both shapes from the same run is close to this, as is shown in Tables I. and II. Actual results do not follow the theory exactly for the reason that the greater volume of the arbitration bar results in its being softer, all other things being equal. There is also a lesser proportion of chilled metal in the round bar.

The worst enemy of the cast-iron test-specimen is the physical defect or flaw. Fewer of the round test-bars contain flaws than of the square. It is apparent that the sharp corners by capillarity or similar influences attract rising bubbles of gas and entrap them in the quicker cooling metal contained in the corners. This effect alone places the round bar superior to the square as a fair representative of a cast.

The figures given in Table I. show that the transverse strength-limits are placed so low that no difficulty should be experienced in filling the requirements.

After obtaining more data it may be found that higher strength-limits are possible and advisable. With the ones given, however, uniformity and good quality are insured, which is the main object to be desired at present.

No upper-strength limit has been placed as this factor is con-

TABLE I.—*Results Obtained from Tests Made with Arbitration Test-Bars.*

No. of Specimen.	Deflection in 12 Inches.	Strength.	Phosphorus.	Manganese.	Sulphur.	Silicon.
	Inches.	Pounds Per Sq. In.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
12,174 }	0.15 }	3,500 }	0.889	0.30	0.128	1.819
12,175 }	0.12 }	3,600 }				
12,266 }	0.09 }	3,500 }				
12,267 }	0.07 }	3,200 }				
12,269 }	0.07 }	3,200 }				
12,270 }	0.08 }	3,200 }	0.653	0.18	0.104	2.040
12,343 }	0.13 }	3,300 }				
12,344 }	0.11 }	3,000 }				
12,345 }	0.12 }	3,200 }				
12,346 }	0.13 }	3,000 }				
12,429 }	0.10 }	2,800 }	0.534	0.36	0.099	1.683
12,430 }	0.08 }	2,800 }				
12,431 }	0.10 }	3,500 }				
12,432 }	0.10 }	3,100 }				
12,433 }	0.13 }	3,500 }				
12,434 }	0.11 }	3,800 }	0.340	0.30	0.113	1.340
12,435 }	0.11 }	3,500 }				
12,436 }	0.12 }	3,400 }				
12,480 }	0.14 }	3,600 }				
12,481 }	0.12 }	3,800 }				
12,546 }	0.07 }	3,200 }	0.681	0.30	0.105	2.092
12,547 }	0.11 }	3,400 }				
12,551 }	0.09 }	2,700 }				
12,552 }	0.09 }	3,000 }				
12,553 }	0.06 }	2,600 }				
12,554 }	0.09 }	3,100 }	0.377	0.36	0.097	1.631
12,638 }	Lost.	3,500 }				
12,639 }	0.10 }	4,100 }				
12,673 }	0.10 }	2,900 }				
12,674 }	0.13 }	3,550 }				
12,675 }	0.11 }	3,500 }	0.580	0.42	0.088	1.974
12,676 }	0.11 }	3,200 }				
12,729 }	0.15 }	3,500 }				
12,730 }	0.11 }	2,800 }				
12,731 }	0.15 }	3,000 }				
12,732 }	0.13 }	3,100 }	0.269	0.30	0.084	1.184
12,733 }	0.17 }	3,500 }				
12,734 }	0.15 }	3,200 }				
12,752 }	0.14 }	2,500 }				
12,753 }	0.17 }	2,500 }				
12,759 }	0.10 }	4,000 }	0.631 (These bars had (Semi-steel.) fins.)	0.43 0.16	0.092 0.170	2.453
12,760 }	0.10 }	4,000 }				
12,780 }	0.09 }	2,700 }				
12,781 }	0.11 }	3,200 }				
12,800 }	0.13 }	2,800 }				
12,801 }	0.13 }	2,800 }	0.690	0.48	0.048	2.695
12,838 }	0.15 }	3,700 }				
12,839 }	0.15 }	3,000 }				
12,840 }	0.14 }	3,100 }				
12,841 }	0.16 }	3,800 }				
12,863 }	0.10 }	3,100 }	0.723	0.30	0.094	1.645
12,864 }	0.10 }	3,100 }				
12,913 }	0.12 }	3,300 }				
12,914 }	0.13 }	3,300 }				
12,915 }	0.13 }	3,200 }				
12,916 }	0.08 }	2,900 }	0.663	0.32	0.129	1.683

The results bracketed together signify that the iron was from the same day's cast—sometimes out of the same ladle, and sometimes not.

TABLE II.—*Results Obtained from Tests Made with 1-in. Square Bars.*

No. of Specimen.	Cast No.	Strength.	Phosphorus.	Manganese.	Sulphur.	Silicon.
		Pounds Per Sq. In.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
12,006	2	2,700	0.765	0.36	0.072	3.305
12,011	2	2,700	0.605	0.24	0.105	2.718
12,027	11/28	2,800	0.551	0.30	0.118	1.673
12,048	11/20	3,000	0.779	0.46	0.095	2.251
12,065	11/27	3,300	0.722	0.36		1.951
12,079	113	2,300	0.595	0.56	0.085	2.016
12,118	2	3,000	0.580	0.16	0.081	2.769
12,157 }	206 }	3,000 }	0.656 }	0.68 }	0.082 }	1.894 }
12,158 }	207 }	3,000 }	0.651 }	0.36 }	0.115 }	1.866 }
12,170	12/10	2,300	0.670	0.88	0.074	2.947
12,198 }	12/5 }	2,600 }				1.434 }
12,200	12/8	2,700	0.535	0.32	0.110	1.640
12,202 }	12/10 }	2,800 }				1.419 }
12,376	12/19	2,400	0.644	0.70	0.097	3.158
12,420 }	214 }	3,000 }	0.626 }	0.38 }	0.085 }	2.031 }
12,421 }	215 }	2,500 }	0.614 }	0.38 }	0.091 }	2.007 }
12,427	2	2,500	0.577	0.24	0.087	2.797
12,761		2,800	Deflection in 12 in.,	0.13 in.		
12,762		3,000	Deflection in 12 in.,	0.13 in.		

trolled by the machining-properties of the iron. It is my opinion that a drilling-test would be the best safeguard against a too hard iron. As not enough data exist at present to make proper commercial limits, this matter is one that should be thoroughly investigated.

A minimum limit for deflection has been placed in the specifications to guard against a strong but brittle iron. Such iron is not often met, but nevertheless it is a factor and should be guarded against. Some of the tests given show a lower deflection, but most of them were due to the fact that the bars were cast with a sectional mold, the attached fins being subsequently ground off; other low deflections were due to accidental defects, and in one set the directions for casting had not been followed and the bars had been roughly ground which removed the skin in spots.

The normal specimens cast as directed were better than the standard demanded and were as good as that warranted by the chemical composition.

TENSILE STRENGTH TEST.

Nothing new is offered in this particular. The strength limits correspond to the ordinary demands so far as made of

the present trade. A uniform gripping-device should be adopted as far as possible for the reason that the grip is of vital importance in testing cast-iron for tensile strength.

DEFINITION.

The classification made is approximate and will naturally be supplemented by buyers who will specify that a given casting must conform to the specifications applying to one of the grades. This will remove all uncertainty as to which class may be meant.

ARBITRATION BAR.

It was the first choice of the committee that a 1.5 in.-bar might be used, in fact, a bar that would be as large as possible in order to be free from all chilling influences and defects resulting from sudden cooling; in short, a less sensitive bar. It was seen that such a bar would break at too great a strength and be beyond the limits of the majority of testing machines now in use in foundries. A diameter of 1.25 in. was therefore adopted as being satisfactory, all things considered.

The question arose of having one standard size of test-bar as compared with having several, in order to make an approximate comparison of thicknesses with the castings under inspection and thus duplicate the actual cooling conditions. This is not possible, because any separate bar must cool more or less slowly than the casting, and any coupon-cast as a part of the casting must be machined before testing. A test of this kind made without the skin does not represent the actual casting, nor can like conditions be duplicated at will in this way.

By having a standard bar it is perfectly possible to estimate the strength of any other bar or casting, just as in the case of the steel maker who rolls a standard test-bar, say $2\frac{1}{2}$ by $\frac{3}{8}$ in. in section from a small 6 in. square test ingot, and from the results obtained is able to foretell the strength of the same steel rolled into a $\frac{3}{8}$ -in. rod, a 0.5-in. angle-iron, or a 1.25-in. plate. It is all a question of heat treatment and speed of cooling, and in this respect cast-iron is similar to steel. Cooling conditions follow very definite laws well recognized by the average founder without his analyzing the reasons. Any grade or quality of cast-iron may be purchased with the arbitration test-bar as specified, as well as by a dozen different sizes of test-bars. It

is a matter of comparison at the best, and one standard is enough.

As a study it would be interesting to cut out specimens from all sizes of castings as far as possible, and the results would form a basis for future comparison, but as a commercial custom this suggestion is practically and commercially out of the question.

The importance of the tensile test has been minimized because of the great difficulty of making true tensile tests. Abnormal strains are sure to creep in except in the most carefully constructed machines operated by the most skilled observers.

The transverse test is within the reach of all and, in fact, corresponds with the conditions of actual use much closer than does the tensile test, and no serious abnormal strains are possible with the ordinary testing machine.

The occasion is likely to arise in which the tensile test will be advisable, to meet which the provision noted in the specifications is inserted. The shape of the specimen resembles quite closely the one in use by the Government, but it has been modified to meet the needs of the piece from which it is to be cut, as well as of other practical considerations. It has been made as short as possible to eliminate the chance of including flaws, and it has been lengthened as compared with the Government specimen, which is likely to give abnormally high results.

CONDITIONS OF CASTING.

Probably the most important source of varying results in cast-iron tests has been the uncertain conditions surrounding molding and casting. There never has been any uniformity in this respect, yet it is a well-known fact that cast-iron is very much influenced by various chilling effects, and is extremely sensitive to all heat-variations. Some foundrymen have made the molds in sand that is quite moist and others in sand that is very dry. Some have knocked the test-bar out of the mold as quickly as it became cool enough to stand it. Some have cast the bar on end, some flat, and some inclined, the variations being nearly as many as the number of foundries. It has therefore been provided that the mold shall be dry and cool before the bar is cast and the other conditions shall be observed which will tend to produce uniform castings.

I note that by some error a provision to prevent the knocking out of the test-bar from the mold has been omitted. This provision was contained in the instructions sent for casting the bars tested, and I doubt that all the conditions were observed, for if one infringement in the matter of casting in a parted mold was made probably there were others. These differences undoubtedly account for some of the abnormal variations.

Some of the bars submitted for the test were cast in a parted mold, producing fins of greater or less thickness, which were chipped or ground off. The result of this condition was that less deflection resulted, even though the fins were placed at the neutral axis of the test specimen.

The provision stating that the test-bars should not be treated in any respect before testing has been found to be most important. The facing of the mold has been particularly specified, so that the test-bar shall strip from the mold in fairly good shape and be ready for the test.

The objection has been made that the bars could not be made sufficiently uniform in diameter—an effect which is more or less true when the iron is cast in a green sand mold; but with the stated casting conditions which prohibit the rapping of the pattern and with the use of a dry mold and a given facing, this objection has almost disappeared and has become of extremely small importance. Measurements made of 20 bars show a maximum variation of but 0.039 in. in an average diameter at the break of 1.236 inches.

TABLE III.—*Measurements of Arbitration Test-Bars at the Point of Rupture.*

No. of Specimen.	Diameter in Inches.	No. of Specimen.	Diameter in Inches.	No. of Specimen.	Diameter in Inches.
1	1.240	8	1.246	15	1.180 This bar cast with fins.
2	1.241	9	1.273	16	1.236 Rounded off by grinding.
3	1.231	10	1.231	17	1.243
4	1.221	11	1.234	18	1.245
5	1.233	12	1.242	19	1.259
6	1.244	13	1.220 This bar was ground smooth.		
7	1.236	14	1.233	20	1.238

It is interesting to note that the only bar cast with fins, that

is, in a parted mold, was the most abnormal of the lot, which ought to be considered a most excellent endorsement of the proposed method of molding.

The question of the character of the supports to be used during the test has been raised, but it is believed that little need be feared on this account, as the testing machines in common use are safe in this matter. In the tests given in Tables I. and II., the point of contact where the load was applied has a radius of about 0.25 in., but no mark is left on the casting, and it is doubtful if this would cause any difference unless the edge were exceedingly sharp, or was a flat surface. The two end-bearings used were flat surfaces intended to rotate on a round bearing. The rotation was not perceptible. Either bearings of this kind, or blunt knife edges, in all probability, would answer equally well.

SPEED OF TESTING.

The time limit of the test has been placed to meet ordinary practice, as near as can be ascertained. In all events it is within reason, and as long as the practice is made uniform by different observers, it is of comparative small moment.

SAMPLES FOR CHEMICAL ANALYSIS.

This simple provision has been made with the understanding that the boring shall be taken after removing all of the surface matter. In case graphitic carbon enters into the case, the sample should be taken across the entire face or cross-section of the bar and thoroughly mixed,—a procedure which is necessary because of the difference in graphitic carbon existing between the exterior and interior metal of a specimen of the size in question.

I recognized that these specifications for gray-iron castings are not ideal from every standpoint, nor is it possible that any commercial ones may be. Theory must yield to practice all along the line, and every engineer or manager discovers this fact very early in his connection with manufacturing conditions.

The Committee believes that by means of these specifications the purchaser of gray-iron castings will be able to obtain a more uniform and reliable product. It is also certain that

there will be correspondingly less friction, because an order for iron-castings will be definite as to quality, and if the foundry makes them to fill the specifications, there can be no dispute as to the quality of the iron furnished because some machinist thinks it machines hard or thinks it looks weak.

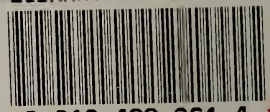
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